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RESEARCH PAPER

Allelopathic effects of *Leucaena leucocephala* leaf litter on some forest and agricultural crops grown in nursery

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Abstract: An experiment was conducted to assess the effect of leaf litter of *Leucaena leucocephala* on two forest crops Sada koroi (*Albizia procera*), Ipil ipil (*L. leucocephala*) and three agricultural crops Falen (*Vigna unguiculata*), Chickpea (*Cicer arietinum*) and Arhor (*Cajanus cajan*) in the nursery of the Institute of Forestry and Environmental Sciences, Chittagong University, Bangladesh, in a Randomized Block Design. Results suggested that leaf litters of *L. leucocephala* induced inhibitory effects on germination and growth of bioassay. It was also found that the effect depended on concentration of extract and litterfall, type of receptor species. Higher concentration of the materials had the higher effect and vice versa. Growth response of receptor crops varied with the variation of leaf litter application. The study revealed that application of low-dose leaf litter specially litter of 10 $g \cdot m^{-2}$ had stimulating effect on shoot growth of *C. arietinum, V. unguiculata* and *A. procera*. While in all other cases significant inhibitory effect was observed and it was significantly increased with the increase of leaf litter application. However, the trend of inhibition was uneven with treatments. Root growth was found to be more affected than shoot growth.

Keywords: allelopathy; agroforestry; choice of species; inhibitory effect; leaf litters; mixed cropping; mixed plantation.

Introduction

Bangladesh, one of the poorest countries in the world, is a densely populated country (834 $persons \cdot km^{-2}$) with an area of about 14.4 million ha and a population of 123.1 million (BBS 2002). Her forest cover is about 14.85% of the land area (BBS 2002). Natural Forests of Bangladesh (which are state-owned) are controlled by the Forest Department and divided into three classes: Hill forest (84%), Inland Sal forest (9%) and Mangrove forest (43%) (Anonymous 1993a). Besides, Village forests cover about one-seventh of the country. Village forest contributes 89% and 80% of total fuel wood and saw or ply logs supply of the countries, respectively (Byron 1985). These forests unevenly distributed are the sources of various forest products, but in generally, they have extremely low productivity (0.5–2.5 $m^3 \cdot ha^{-1} \cdot a^{-1}$) (Anonymous 1993b). Despite a very low per capita consumption of wood (fuelwoods 0.06 m^3 and timber 0.018 m^3) (Bhuiyan 1993), the supply from the forest is far beyond the demand. There remains a wide gap between the supply and demand of forest products (5 million m^3) (Anonymous 1993b). The present forest system of Bangladesh is unable to meet the current demand of forest products for its people due to overexploitation of resources, destruction of forests by different agents, shortage of quality seed supply and planting stocks, increased cost of raising plantation and shortage of sufficient research and technical information. Plantation of Bangladesh is generally done by traditional method by seeds and seedlings. For this program, seeds are generally collected from existing plantations and natural stands. Pests and diseases often damage these seeds. As a result, problems like non-uniformity of timber, slow growth, average low quality and quantity exists in plantation programs. To get rid of such worse situation Bangladesh Forest Department introduce Ipil ipil (*Leucaena leucocephala*) in August 1977 from the Philippines (Das et al. 1985). People widely prefer fast growing multipurpose trees for their plantation programs. From that aspect it was found that Leguminosae is the best because of its fast growing, nitrogen-fixing, coppicing ability to adapt in wide range of environment. Of all tropical legumes, *Leucaena* probably offers the widest assortment of uses. Due to its multipurpose utility and wide range of ecological amplitudes (especially suitable to Bangladesh Environment) the species is recommended road side as well as khet land other than forest land (Banik 1992). However, Ipil ipil, a multipurpose, fast growing species is widely

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used as an important associated tree species in many agroforestry programs in Bangladesh. While planning mixed plantation, knowledge on allelopathic interactions are important for obtaining better output. Allelopathic interactions are widely known in different groups of plants such as algae, lichens, crops, and annual and perennial weeds (Rice 1984; Putnam 1986; Horsley 1991; Lawrey 1993; Inderjit and Dakshini 1994a, 1994b). Chemicals that inhibit the growth of some species at certain concentrations can stimulate the growth of the same or different species at lower concentrations (Rice 1984). Hence, it should be expected that due to the perceived ambiguous nature of allelopathy, the phenomenon is sometimes hesitantly accepted, or even refuted, as an important factor in crop production. From agronomic point of view, allelopathy is of great interest because it makes possible the establishment of agroforestry farm with plants that are not strongly allelopathic between themselves. Therefore, it can ensure a stable agro ecosystem with positive effect on productivity and longevity. In the recent past allelopathic research has obtained momentum with few species in laboratory and also in nursery stage. Allelopathic effects of aqueous leaf extracts of *Acacia auriculiformis* (Hoque et al. 2003a), *Azadirachta indica* (Hoque et al. 2003b), *Eupatorium odoratum* (Hoque et al. 2003c), *Albizia saman* (Hoque et al. ,2003d), *Leocaena leococephala* (Uddin et al. 2000), *Albizia saman* (Uddin et al. 2007) have been studied in Bangladesh so far. Recently Ahmed et al. (2008) reported the allelopathic effects of leaf litter of *Eucalyptus camaldulensis* on some forest and agricultural crops. Although there were some reports on allelopathic effects of *Leucaena* available (Kuo et al. 1982; Chou and Kuo 1986; Uddin et al. 2000), most of them were laboratory-based study that rarely reflected the field condition. Therefore the objective of the present study is to elucidate the allelopathic potentiality of *Leucaena leucocephala* leaf litter in the nursery bed.

Materials and methods

Ipil ipil (*Leucaena leucocephala* (Lam) de Wit) was considered as the donor plant and the receptor agricultural crops were Falen (*Vigna unguiculata*), Chick pea (*Cicer arietinum*) and forest crops were Arhor (*Cajanus cajan*), Sada koroi (*Albizia procera*) and Ipil ipil. The experiment was conducted in the nursery of the Institute of Forestry and Environmental Sciences, Chittagong University, maintaining a Randomized Block Design. The leaf litter of ipil ipil was collected from 8 years old plantation. They were then air dried and grounded. The nursery bed was thoroughly prepared by adding 15 cm topsoil from the barren hill. The bed was fairly leveled and all weeds and other debris were removed. Finally the grounded leaf litters were mixed with soil uniformly in following proportions representing the treatments of:

T_0= Seeds of receptor plants grown in bed with soil only (Control);
T_1= Seeds of receptor plants grown in bed mixed with litter of 10 $g{\cdot}m^{-2}$;
T_2= Seeds of receptor plants grown in bed mixed with litter of 50 $g{\cdot}m^{-2}$;
T_3= Seeds of receptor plants grown in bed mixed with litter of 100 $g{\cdot}m^{-2}$;
T_4= Seeds of receptor plants grown in bed mixed with litter of 150 $g{\cdot}m^{-2}$ and
T_5= Seeds of receptor plants grown in bed mixed with litter of 200 $g{\cdot}m^{-2}$.

The litter was allowed to decompose for two months and the plots were watered periodically. Then seeds of tested plants were sown. Germination of the crops was regularly recorded up to the notice of last germination. Watering and weeding was regularly done. The agricultural crops were harvested after one and half month and forest crops after two and half months. The effect was compared with control. The data were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT). Ratio of germination and elongation were calculated as suggested by Rho and Kil (1986):

$$RGR = \frac{GR_t}{GR_c} \times 100 \quad (1)$$

where, RGR is the relative germination ration, GR_t the germination ratio of tested plant, and GR_c is the germination ratio of control.

$$RER = \frac{ML_t}{ML_c} \times 100 \quad (2)$$

where, RER is the relative elongation ratio of shoot, ML_t the mean shoot length of tested plant, and ML_c is the mean length of control.

For the calculation of percentage of inhibitory effect on the radicle and plumule elongation, percentage to the control was calculated as per formula evolved by Surendra and Pota (1978):

$$I = 100 - (E_2 \times 100 / E_1) \quad (3)$$

where, I is the % inhibition, E_1 the radicle and plumule elongation of control plant and E_2 the radicle and plumule elongation of treatment plant.

Results

Shoot growth

Response of shoot growth of receptor crops varied with the variation of leaf litter application. The study revealed that T_1 treatments had stimulating effect on shoot growth of all crops compared to control except *L. leucocephala* itself. In all other cases significant inhibitory effect was observed and it was significantly increased with the increase of leaf litter application. However, the trend of inhibition was uneven with treatments. Stimulatory effect was observed in T_1 treatment on *C. arietinum*, *V. unguiculata* and *A. procera* as 10.5%, 4.5% and 0.23% respectively (Table 1). The highest relative elongation ratio (RER)

of shoot (110%) was found in *C. arietinum* at T_1 treatment followed by *V. unguiculata* (104%) at the same treatment. On the contrary, the lowest RER was found in *C. arietinum* at T_5 treatment (Fig. 1). Among the test crops *V. unguiculata* was the least affected of all crops.

Table 1. Shoot length of seedlings grown in nursery bed on the application of different proportion *L. leucocephala* leaf litter

Treatment	Agricultural crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	40.22 a	55.44a	33.71 ab	34.75 a	125.33 a
T_1	44.40 a (+10.5)	52.44b (-5.4)	35.22 a (+4.5)	34.83 a (+0.23)	105.25 b (-16)
T_2	30.00 c (-25.4)	50.44c (-9)	33.11 b (-1.8)	29.05 b (-16.4)	96.08 c (-23.3)
T_3	35.61 b (-11.5)	55.11a (-0.6)	32.55 b (-3.4)	26.55 bc (-23.6)	86.83 d (-31.7)
T_4	30.33 c (-24.5)	53.66ab (-3.2)	28.55 c (-15.3)	23.33 c (-32.9)	97.58 c (-22.1)
T_5	24.39 d (-39)	53.88ab (-2.8)	29.33 c (-13)	25.94 bc (-25.3)	77.88 e (-37.9)

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT. Value in the parenthesis indicates the stimulatory (+) or inhibitory (-) effects in comparison to control (T_o).

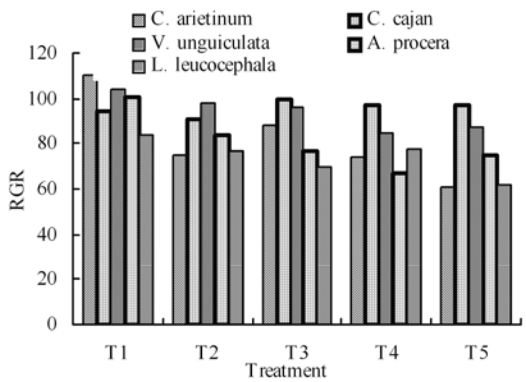

Fig. 1 Relative elongation ratio of shoot of seedlings grown in nursery bed treated with different proportion of *L. leucocephala* litter

Root growth

The effect of *L. leucocephala* on primary root growth of tested seedlings grown in nursery bed showed that the root length of all crops in all treatments had shorter length than that of control except *L. leucocephala* itself. It was stimulated at T_1 treatment (Table 2). For seedling growth, root elongation was affected more than shoot elongation in all the crops with the suppressing effect being most pronounced in T_5 treatment followed by the treatments in descending order. However, relative elongation ratio (RER) of root was the highest (115%) in *L. leucocephala* at T_1 treatment while the lowest (59%) was found in *A. procera* at T_5 treatment (Fig. 2).

Table 2. Root length of seedlings grown in nursery bed on the application of different proportion of *L. leucocephala* leaf litter

Treatment	Agricultural crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A procera*	*L. leucocephala*
T_0	12.94 a	13.8 a	23.17 a	22.17 a	40.0 b
T_1	11.50 b (-11.1)	12.16 ab (-11.9)	19.76 b (-14.7)	21.27 a (-4)	45.83 a (+14.6)
T_2	10.74 b (-11.1)	10.5 bc (-23.9)	17.17 c (-25.9)	20.11 b (-9.3)	34.33 d (-14.1)
T_3	11.66 ab (-9.9)	11.83 b (-14.2)	20.17 b (-12.9)	19.83 b (-10.5)	29.33 e (-26.7)
T_4	10.22 b (-21)	10.61 bc (-23.1)	21.28 b (-8.1)	15.72 c (-29)	44.5 a (+11.2)
T_5	9.61 b (-25.7)	9.83 c (-29)	16.61 c (-28.2)	13.0 d (-41.3)	37.67 c (-5.8)

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT. Value in the parenthesis indicates the stimulatory (+) or inhibitory (-) effects in comparison to control (T_o).

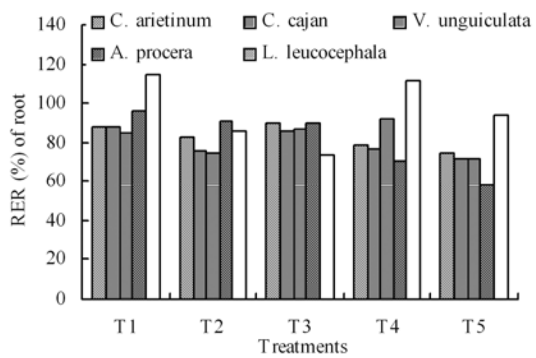

Fig. 2 Relative Elongation Ratio of root of seedlings grown in nursery bed treated with different proportion of *L. leucocephala* litter.

Collar diameter (mm)

Collar diameter of tested seedlings following treatments of different leaf litters of *L. leucocephala* showed statistically no significant variation among the treatments. However, increasing suppressive effect was observed with the increased leaf litter application. Highest inhibitory effect (-31%) was found on *C cajan* at T_5 treatment while the lowest (-1.6%) was on *L. leucocephala* itself at T_1 treatment. On the contrary highest stimulatory effect (+23%) was found on *A. procera* at T_1 treatment and lowest (+0.36%) on *V. unguiculata* at the same treatment (Table 3).

Leaf number

Table 4 showed the leaf number of tested forest and agricultural crops in response to the application of different percentage/dose of *L. leucocephala* leaf litter in nursery bed. The result revealed that leaf number of seedlings following treatments was different

significantly. In most cases, highest effect was observed in T_5 treatments followed by T_4 treatment. However, the trend of effect was uneven with the treatments. Highest inhibitory effect (-51%) was found on *C arietinum* at T_5 treatment while the lowest (-0.6%) was on *L. leucocephala* at both T_5 and T_4 treatments. On the contrary both highest (+14%) and lowest (+4%) stimulatory effect were found on *L. leucocephala* at T_1 and T_2 treatment respectively. Among all the test crops, *L. leucocephala* was found to be least affected in this respect (Table 4).

Table 3. Collar diameter (mm) of seedlings grown in nursery bed on the application of different proportions of *L. leucocephala* leaf litter

Treatments	Agricultural crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A procera*	*L. leucocephala*
T_0	4.22 a	3.90 a	5.57 a	2.73 a	8.20 a
T_1	3.25 a	3.67 a	5.59 a	3.36 a	8.07a
	(-3)	(-5.9)	(+0.4)	(+23)	(-1.6)
T_2	3.98 a	3.37 a	5.33 a	3.02 a	7.75 a
	(-5.7)	(-13.6)	(-4.3)	(+10.6)	(-5.5)
T_3	3.58 a	3.33 a	5.85 a	2.87 a	6.65 a
	(-15.2)	(-14.6)	(+5)	(+5.1)	(-18.1)
T_4	3.21 a	3.20 a	4.71 a	2.30 a	7.35 a
	(-23.9)	(-17.4)	(-15.4)	(-15.7)	(-10.4)
T_5	2.94 a	2.70 a	4.92 a	2.65 a	6.38 a
	(-30.3)	(-30.8)	(-11.7)	(-2.9)	(-22.2)

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT. Value in the parenthesis indicates the stimulatory (+) or inhibitory (-) effects in comparison to control (T_o)

Table 4. Number of leaves on seedlings grown in nursery bed on the application of different proportions of *L. leucocephala* leaf litter

Treatments	Agricultural crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A procera*	*L. leucocephala*
T_0	86.00a	22.57a	22.50b	8.00a	18.66b
T_1	65.22b	20.67ab	21.78b	5.55b	21.35a
	(-24.2)	(-8.4)	(-3.2)	(-30.6)	(+14.4)
T_2	59.88c	20.11b	25.55a	4.67b	19.44ab
	(-30.4)	(-10.8)	(+13.5)	(-41.6)	(+4.2)
T_3	50.33d	22.11a	19.44c	4.86b	17.22b
	(-41.5)	(-8.1)	(-13.6)	(-39.2)	(-7.7)
T_4	51.88d	20.67ab	16.66d	4.89b	18.55b
	(-39.7)	(-2.4)	(-25.9)	(-38.9)	(-0.6)
T_5	41.88e	18.22c	16.67d	5.67b	18.55b
	(-51.3)	(-19.3)	(-25.9)	(-29.1)	(-.06)

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT. Value in the parenthesis indicates the stimulatory (+) or inhibitory (-) effects in comparison to control (To).

Root diameter (cm)

Expansion of secondary roots of test crops grown in nursery bed were measured and expressed as average root diameter. Significant hindrance of root diameter was found in *L. leucocephala* in all treatments (Fig. 3). However, root diameter of *A. procera* showed a decreasing trend from lower dose to higher dose of leaf litter application, the differences were not significant among the treatments. Reduction in root diameter of *L. leucocephala* and *A. procera* was 21% and 2%, respectively.

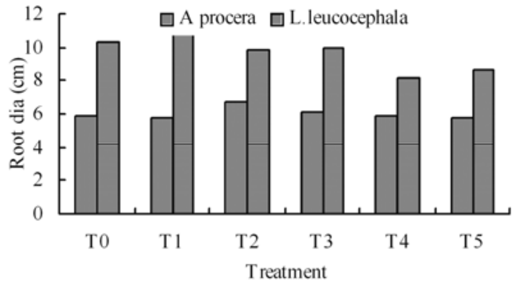

Fig. 3 Root diameter (mm) of different receptor crops to the application of different proportions of *L. leucocephala* leaf litter in Nursery bed

Discussion and conclusion

The present study reveals that *L. leucocepha* has inhibitory effect of on germination and growth of *V. unguiculata, C. arietinum, C. cajan, A. procera* and *L. leucocephala*. Higher litter application induced maximum growth inhibition. This finding is supported by the results of Melkania et al. (1982) and Kou et al. (1982), who identified several phenolic compounds and mimosine as well as unknown flavonoids, in the *L. leucocepha* leaf extracts. These compounds along with mimosine present in leaf can be responsible for retardation of germination and other growth parameter of *V. unguiculata, C. arietinum, C. cajan, A. procera* and *L. leucocephala* in the present study. Pound and Martinez Cairo (1983) provided an excellent review of the chemistry of *leucaena*. Allelopathy has been attributed to *leucaena* leaves, based on inhibitions of seed germination with mimosine itself and with leaf extracts. The extracts contained several common phenolics of toxic potential, e.g., ferulic and coumaric acids. Extrapolations to the field are fraught with hazards, and there has been no clear documentation of *leucaena*-induced allelopathy under field conditions. *Leucaena* suppresses nearby herbs largely through competition for light and water (Brewbaker 1987). Jones (1979) reported the foliage and pods of leucaena contained the toxic amino acid mimosine which might reach 12% of the dry matter in growing tips but was less in young leaves (3%–5% of dry matter). Lal (1989) reported that Maize and cowpea germination and seedling establishment were significantly suppressed by *Leucaena*. He claimed allelopathic effect was one of the reasons for suppression. He argued that perhaps phytotoxic chemicals were leached from the decomposing leaves and shoots of *Leucaena* that caused germination suppression. Chouhan et al. (1992) reported suppressive effect of leaf litters of *L. leucocephala* was found highest compared to *Eucalyptus* hybrid and *Prosopis juliflora* on dry matter production of grasses under the fuelwood plantation at Udaipur, Rajasthan in 1986 under rainfed conditions. Akbar (1990) found no significant differences in wheat yield under *E. camaldulensis, A. procera, M. alba* and *L. leucocephala* in Pakistan. Ramshe et al. (1990) reported the allelopathic effect of *L. leucocephala* was higher than *Eucalyptus* spp hybrid and *Dalbergia sissoo* on agricultural crops grown be-

tween rows. Srinivasan et al. (1990) reported the yield reduction of Eleven agricultural crops those were interplanted with 3 multipurpose tree species (*E. tereticornis., Casuarina equisetifolia* and *L. leucocephala*) under rainfed condition. They found maximum yield inhibition under *L. leucocephala* but they argued that the yield reduction was attributed primarily to reduced light transmission.

However the extent of inhibition was specific to the receptor plants. Among the all test plants, *C. cajan* and *V. unguiculata* showed compatible growth. Considering the two forest species, *A. procera* showed more compatible growth while *L. leucocephala* itself showed less compatible i.e. autoallelopathy existed here. Such interspecific influences (autotoxicity or autoallelopathy) have been reported by Bansal (1994). Therefore, in mixed plantation, *A. procera* may be a good associated species of leucaerna and in agroforestry *C. cajan,* and *V. unguiculata* may be the better compatible crops.

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